Triple ACT Advanced Compaction Technology

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Enabling binder jet 3D printing for specialty materials

Desktop Metal

WHITE PAPER

The Challenge:

At first glance, 3D printing using binder jetting sounds easy. You lay down a thin layer of powder, inkjet a binder onto the particles where you want them to stick together, and then repeat, layer-by-layer, until your desired object takes form. For 3D printing metal, once you have a cured "green part," you sinter it in a furnace, so all of the particles fuse isotropically into the final object.

If only developing a breakthrough technology were that easy.

To print high-quality parts in premium materials using binder jetting, your 3D printer must print the finest powders possible. While Desktop Metal binder jetting printers have processed even finer powders, they typically process MIM powders with a median particle size of 8-10 microns. Using very fine powders such as these helps to ensure the particles can sinter together to form a dense, uniform microstructure that delivers reliable functionality and performance.

Unfortunately, these fine powders are the most challenging materials to process. For starters, it's difficult to uniformly deposit them onto a flat surface. Similar to baking powder, these small particles are prone to caking and clumping. When you release them onto a surface, they can form dust clouds. Once you do get them into place, a drop of liquid binder can cause them to ripple or displace. What's more, the bigger the surface area you're trying to cover, the more challenging it is to create a uniform printing environment.

So, to successfully 3D print a part using binder jetting technology in a specialty material, you must understand and tightly control your powder recoating process. The final test of your 3D printer's quality will ultimately be revealed after sintering, where any flaws in the binding of the powders are exposed.

The Solution:
Triple ACT

Enter Triple Advanced Compaction Technology (ACT). Patent pending Triple ACT makes the Desktop Metal X-Series of binder jetting systems uniquely positioned to process a wide range of premium materials, including aluminum, copper, and tungsten alloys, metal composites, and technical ceramics, such as silicon carbide and boron carbide (B_4C).

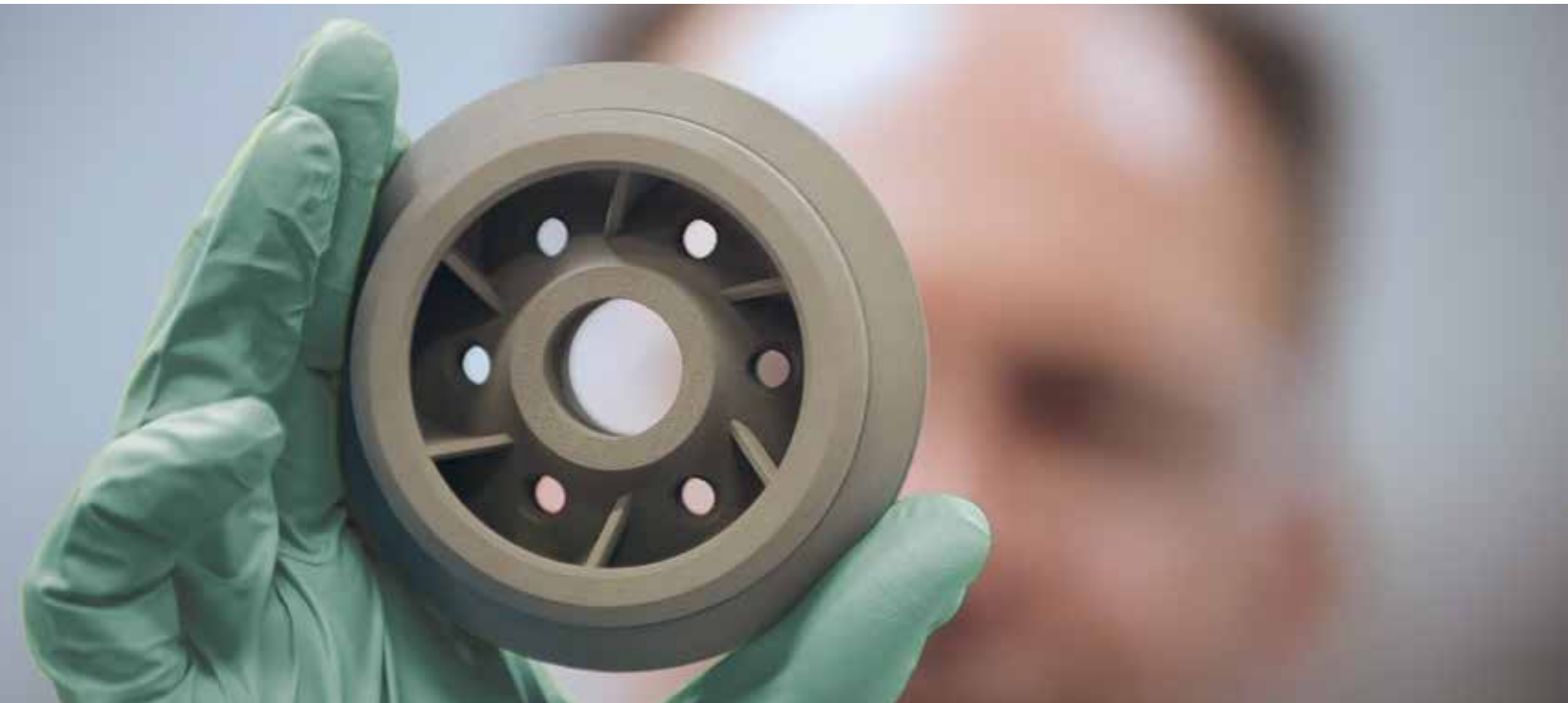
The patented Triple ACT system solves three of the most challenging aspects of creating a thin, uniform layer of powder for a print job: dispensing, spreading, and compacting fine powders.

Because each function is truly unique in its objective, our expert team set about designing a three-tiered solution.

A Triple Challenge

1. Dispensing
2. Spreading
3. Compacting

20+ Years in the Making



ACT One:

Dispensing — A unique ultrasonic hopper

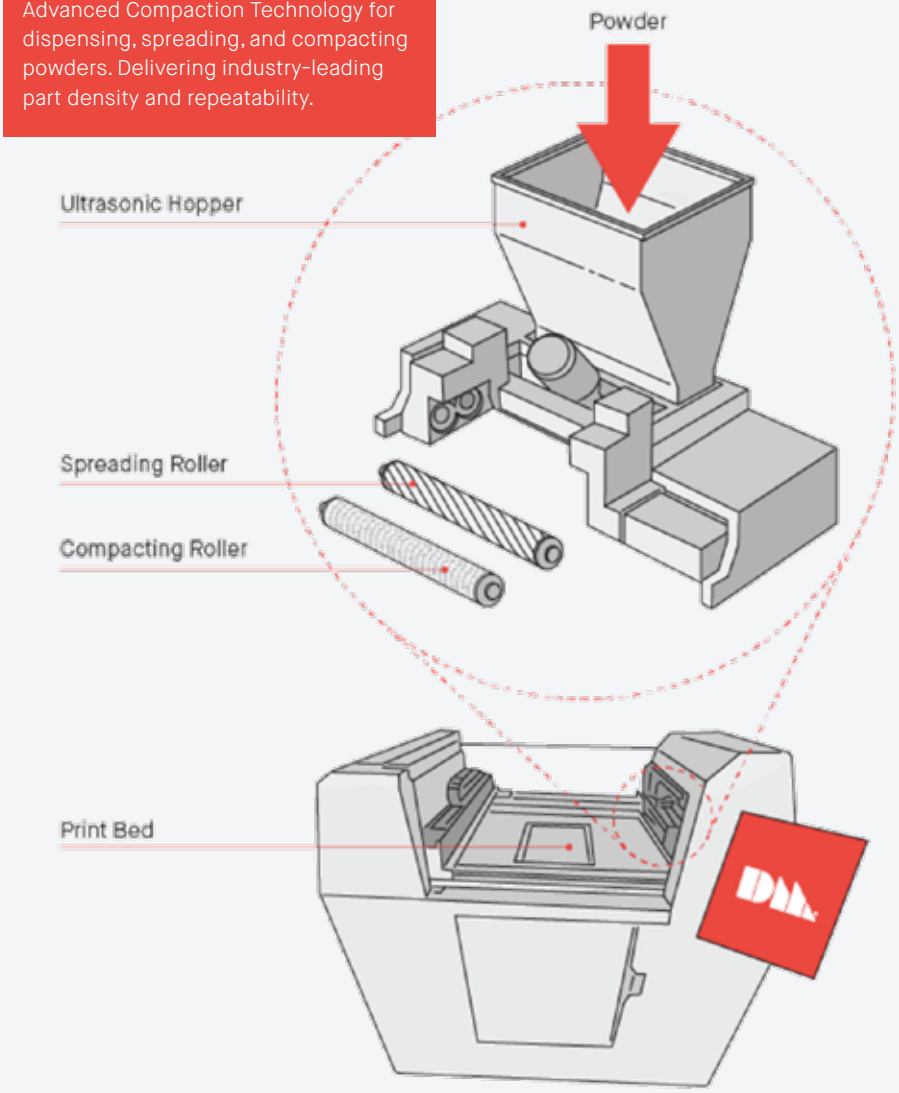
To solve the problem of caking, clumping, and powder clouds, our team studied powder-handling techniques used by other industries processing fine powders to find the method that delivered the best results. They found systems that used shaking and pulsing, sometimes in specific rhythms, to manage and move challenging fine powders. But there were limitations: most powder-dosing systems are used to place powder in one tight location, not across a wide build area, so our team used their research to invent a unique solution.

With trial and feedback over machine generations, we developed and refined Step One of the Triple ACT system: a unique hopper design with a dispensing screen that ultrasonically vibrates to release a highly controlled dose of powder as it quickly moves across the span of a print bed.

The new, scalable approach releases a consistent and fine layer of powder particles across large build areas. The dispensing screen is also easily adjusted to account for powders with extremely high, or low, levels of flowability.

After powder is precisely dosed in locations across the bed, it must then be evenly spread and compacted — |ACTs Two and Three — in order to deliver a quality print layer, and the highest ultimate part density.

Triple ACT
Advanced Compaction Technology for dispensing, spreading, and compacting powders. Delivering industry-leading part density and repeatability.



ACT Two:

Spreading — a new roller with a knurl design

For many generations of binder jet 3D printers, a similar method of spreading and compacting the powder across the bed was used: a rolling pin.

This simple approach worked with limited success in the smallest build areas. But as binder jet 3D printers began to scale up in size, it wasn't as effective in consistently spreading the particles of specialty materials across the entire bed area evenly. While the rolling pin did help to evenly spread the powder to an extent, it was actually more effective at compacting the powder close to its original drop location.

So, our team decided to separate the spreading and compacting functions, using two new roller pin designs for each function. The new spreading roller is truly unique, with a specific knurl design to more evenly spread the powder after dispensing, creating a uniform pile of powder for the compacting roller to interact with.

The special knurl face helps to evenly pick up and spread specialty powders evenly over a certain height setting to ensure the powder is spread in such a way to remain consistent. The knurl pattern in the powder bed also helps mitigate printing defects caused by "short-spreading" of powder if not enough material is locally dispensed.

ACT Three:

Compacting — a critical final step for dense parts

The final step of the Triple Act is compacting the now evenly spread powder. The goal is to press the particles tightly together so when the inkjet head doses binder onto them, it can form the most dense bond possible.

However, the compaction pressure must also not be too great, or else it could damage layers that have already been printed below the new recoating layer and are not yet fully cured. While each 3D printed layer on a Desktop Metal X-Series system is heated after binder is applied and before the new coating of powder is laid down, the layer is not completely cured or dry.

Imagine adding a new layer of sand to a damp sand castle at the beach, and then using a rolling pin on top of it to even it out. You have to use just enough force to compact the particles, but not so much that you crush the work you've already done below the new layer.

In binder jetting, these already-printed layers are sensitive to disruption in the X, Y, and Z directions, and so compaction force and the precise Z-layer at which pressure is applied must be tightly controlled.

What's more, the Triple ACT compacting roller on X-Series machines also features a special surface finish designed to not further spread or move the powders during this final step.

Independent Research:

Roller systems can improve part quality

Research performed by the University of Waterloo in Ontario, and published in the peer-reviewed journal, Additive Manufacturing, confirmed that a roller system is vital to the quality of metal 3D printed parts using binder jet technology:

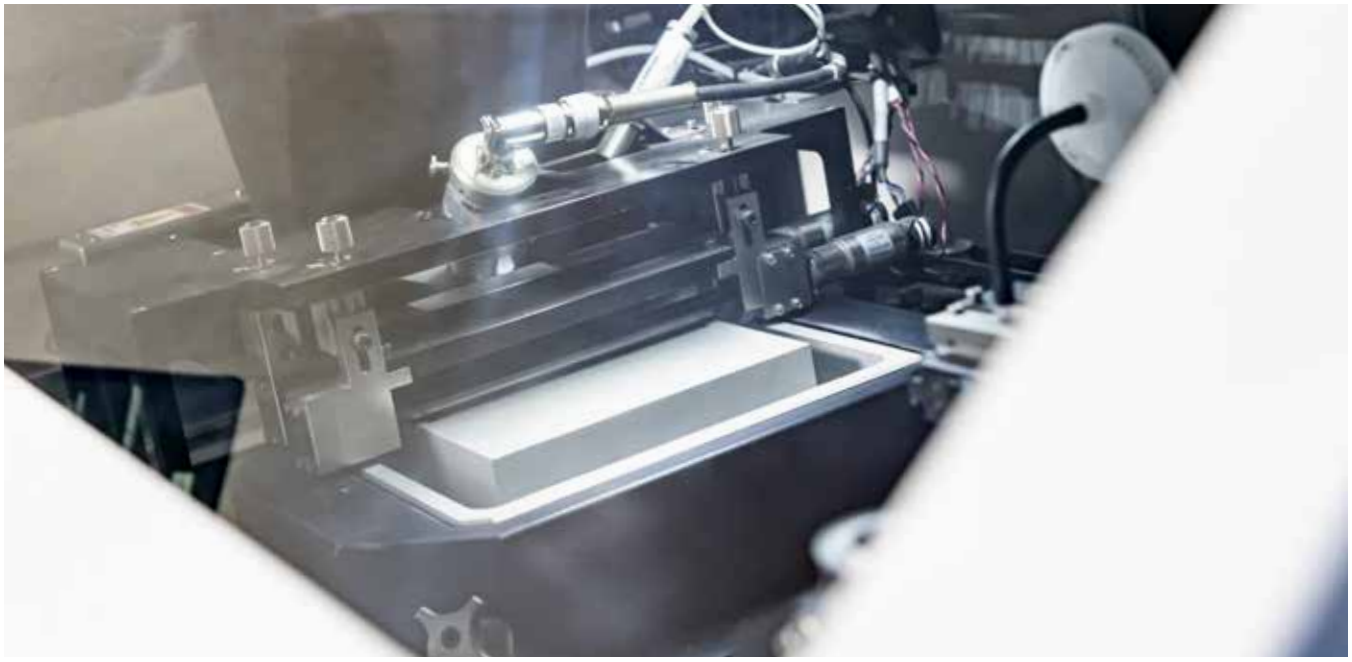
On Higher Green Part Density

"Based on the density values, it is seen that powder compaction through roller rotation plays an important role in increasing green density," adding that the roller system "leads to higher green densities when the roller is actuated."

On Delivering Less Accuracy Distortion in X and Y

"The powder particles are pushed closer together with each spread. The compaction of the powder layers is also beneficial in minimizing the seeping of the liquid binder outside the intended part area. This seeping out effect can be detrimental as it can lead to layer shifting. In fact, layer shifting is consistently observed in many of the samples printed with the deactivated roller rotation."

Reference: Issa Rishmawi, Mehrnaz Salarian, Mihaela Vlasea. (2018). Tailoring green and sintered density of pure iron parts using binder jetting additive manufacturing. Additive Manufacturing, Volume 24, 508-520. ISSN 2214-8604. Retrieved from https://doi.org/10.1016/j.addma.2018.10.015



An Advanced Recoating Solution:
Smart dispensing, spreading, and compacting

Taken together, the Triple ACT system for precision dispensing, spreading, and compacting fine powder delivers industry-leading part density and the repeatability required for premium material 3D printing, especially in larger build areas.

The Desktop Metal Triple ACT system achieves densities of 97% or greater, depending on the material and how much density a customer desires, which can now be precisely dialed in with Triple ACT and other process controls on X-Series binder jetting systems.

What's more, part density variability across the build area can be up to 0.3% depending on material — an improvement of 90% over previous binder jetting printing systems before deployment of the Triple ACT with layer thicknesses that can go down to 30 microns.

Previously, part quality on the farthest edges of the build area showed less density than those in the centermost areas of the print bed.

Desktop Metal X-Series binder jetting 3D printers enabled with the exclusive Triple ACT system are production ready Additive Manufacturing 2.0 systems.

The Desktop Metal X-Series

Binder jetting specialty materials on the Desktop Metal X-Series was developed with scalability in mind to drive innovative applications in specialty materials with repeatable performance across a range of machines. The InnoventX is the perfect R&D and prototyping machine often used before scaling to production on the X25Pro and X160Pro. Features of the X-Series machines like top-of-the-line piezoelectric printheads and Triple ACT powder compaction deliver industry-leading density in a variety of materials, including hard to process powders like hard metals and tool steels or technical ceramics like silicon carbide.

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X160Pro binder jet system ramps up applications developed on the InnoventX or X25Pro to mass production volumes

About Desktop Metal Inc.

Desktop Metal (NYSE:DM) is driving Additive Manufacturing 2.0, a new era of on-demand, digital mass production of industrial, medical, and consumer products. Our innovative 3D printers, materials, and software deliver the speed, cost, and part quality required for this transformation. We're the original inventors and world leaders of the 3D printing methods we believe will empower this shift, binder jetting and digital light processing. Today, our systems print metal, polymer, sand and other ceramics, as well as foam and recycled wood. Manufacturers use our technology worldwide to save time and money, reduce waste, increase flexibility, and produce designs that solve the world's toughest problems and enable once-impossible innovations. Learn more about Desktop Metal and our #TeamDM brands at www.desktopmetal.com.